Detecting Seasonal Changes in Benthic Fauna Composition Between Hanko and Tammisaari in the Baltic Sea

Sirja Susanna Kivelä

Bachelor Thesis for Degree Programme in Integrated Coastal Zone Management

Raseborg 2014

BACHELOR'S THESIS

Author: Sirja Kivelä

Degree Programme: Integrated Coastal Zone Management, Raasepori

Supervisors: Janica Borg, Purba Pal, Anna Granberg

Title: Detecting Seasonal Changes in Benthic Fauna Composition between Hanko and Tammisaari in the Baltic Sea

Date 21.3.2014	Number of pages 19	Appendices 1

Abstract

The Baltic Sea has pronounced seasons that bring with them annually occurring phenomena such as algal blooms in the spring and summer and annual hypoxic maximums in early autumn. The purpose of this thesis is to explore seasonal changes in the macrozoobenthos in near shore soft sediment habitats in the Gulf of Finland, between Hanko and Tammisaari. A total of 144 benthic samples were collected from 32 soft-sediment beaches, divided into 4 area types. Samples were collected both in the spring and the summer, and their contents were analyzed to the lowest practical taxon. Shannon-Wiener Biodiversity Indices and species richness were calculated for both seasons within each location group and compared between seasons. The similarities between species assemblages were explored with ANOSIM and SIMPER analyses. Biodiversity was not found to vary significantly between seasons at any location. Species richness was found to increase between spring and summer in Outer Archipelago 1. Slight differences in species assemblages were seen in Outer Archipelago 1 and 2. Changes were found in the abundance of nematodes, which made up the most abundant species group in all location groups in the summer samples, despite making up the most prominent group of fauna only in the Inner archipelago in the spring. Results of this study permit very limited speculation and further study is needed to examine the causes behind changes and the significance of such findings. Selecting more specific taxonomic resolutions and purposeful sampling times are proposed as measures to achieve more specific and relevant results.

Language: English	Key words: Macrozoobenthos, benthic fauna, Baltic Sea, seasonality, soft sediment habitats

Table of Contents

1 Introduction

1.1 Aims and Objectives of Thesis

This study aims to explore seasonal changes in the macrozoobenthos in near shore soft sediment habitats in the Gulf of Finland, between Hanko and Tammisaari.

1.2 Characteristics of the Baltic Sea

The Baltic Sea is a brackish water body situated between 53°N to 66°N latitude and from 20°E to 26°E longitude (Save Our Baltic Sea, 2009) bordered by nine countries, namely Finland, Sweden, Denmark, Germany, Poland, Latvia, Lithuania, Estonia and Russia (WWF, n.d.). It is connected to the North Sea via a narrow strait between Denmark and Sweden, limiting the salinity of the sea, which receives ample freshwater from its large catchment area. With a surface area of about 4.2×105 km^2 and a volume of about 22×103 km^3, it makes up one of the largest brackish water bodies in the world (Ojaveer, et al., 2010).

Throughout its relatively young ecological age of 10,000 years, the Baltic Sea has alternated between marine, limnic and brackish conditions (Rumohr, et al., 1996). This young age has not allowed for the evolution of specific brackish water species, causing many species to function at the limits of their respective environmental tolerances. Only one species is known to be endemic to the Baltic Sea (Ojaveer, et al., 2010).

One of the main threats to the viability of the Baltic Sea is hypoxia (Conley, et al., 2011). Although the Baltic Sea has faced recurring hypoxic episodes throughout the Holocene era, since the end of the last ice age, the increases in hypoxic conditions during the last century are mainly attributed to anthropogenic sources, mainly eutrophication resulting from industrial agricultural nutrient runoff (Zillén, et al., 2008). Studies done using the area of laminated sediments, used as an indicator of hypoxic conditions, have proposed that hypoxic areas have increased four-fold in the past 50 years (Jonsson, 1990). Traditionally seen more as a problem of deeper Baltic waters with a pronounced stratification resulting from the halocline, recent studies have shown that hypoxia has also increased dramatically in the Baltic coastal zone (Conley, et al., 2011). This effect is exacerbated by stratification caused by seasonal temperature changes combined with reduced water circulation and the decomposition of phytoplankton and drifting algal mats (Ibid.).

1.3 Seasonality

The Baltic Sea has pronounced seasons with surface temperatures varying from more than 20^{o}C in the summer to having a full ice cover in the winter. The seasons bring with them annually occurring phenomena such as algal blooms in the spring and summer, and annual hypoxic maximums which occur in August and September (Conley, et al., 2011). Two notable algal blooms are observed annually – the nitrogen-fueled diatom and dinoflagellate bloom reaching the Gulf of Finland with the melting of the sea ice in April and lasting until May, and the phosphorous-limited cyanobacteria bloom which occurs late in the summer (WWF Baltic Ecoregion Programme, 2009).

In addition to triggering seasonal environmental events, the temperature variations cause stratification in coastal zones of the Baltic preventing vertical mixing of water in the water column in a similar fashion to the halocline at depths of the Baltic Sea basin (Conley, et al., 2011). This division that keeps the oxygen-rich surface waters from reaching the benthic environment further exacerbates the problem of hypoxia in the sea bottom.

1.4 Soft-sediment Macrozoobenthos

Soft-sediment zoobenthic communities play a vital role in the functioning of the entire Baltic Sea ecosystem through the ecosystem services and functions they provide. In addition to providing nutrition for the higher trophic levels of the ecosystem, they modify the habitat in a way which allows oxygen to penetrate the sediments and aid in the degradation of organic matter (HELCOM, 2009). For example, nematodes have been shown to contribute to nutrient cycling as well as sediment bioturbation, enhancing oxygen fluxes and increasing microbial activity in the sediments (Wilson & Kakouli-Duarte, 2009). Some species of nematodes have even been shown to withstand anoxic conditions (Ibid.). As hypoxia resulting from eutrophication makes up one of the main threats to the viability of the Baltic Sea, the role of benthic macrofauna cannot be overlooked when determining strategies to improve the health of the Baltic Sea ecosystem.

1.4.1 Main Species and Species Groups in the Study

The grouping of the species observed in this study is described in Table 1.

Species group	**Brief species group description**	**Examples from the Baltic Sea**
Amphipoda	Shrimp-like crustaceans	Gammarus spp, Monoporeia affinis, Bathyporeia pilosa
Bivalvia	Commonly known as clams and mussels, Bivalvia constitute a taxonomic class in the phylum Mollusca, mainly filter feeders	Mytilus edulis, Macoma baltica, Mya arenaria, Cerastoderma glaucum
Nematoda	Roundworms, very simple, non-segmented anatomy	At least 200 species, no existing list of species
Oligochaeta	Segmented (=annelid) worms, resembling common earthworms in structure and appearance	
Polychaeta	Marine annelid (=segmented) worms, also known as bristle worms due to bristle-like extensions that are present in most segments	Marenzelleria viridis, Nereis diversicolor, Polydora redeki, Manayunkia aestuarina, Fabricia, Fabricola,Pygospio elegans, Harmothoe spp.
Marine Gastropoda (Marine)	Commonly known as snails and slugs Gastropoda constitute a taxonomic class in the phylum Mollusca	Hydrobia ulvae, Hydrobia ventrosa, Limapontia capitata
Fresh water Gastropoda (Fresh)	Commonly known as snails and slugs Gastropoda make up a taxonomic class in the phylum Mollusca	Theodoxus fluviatilis, Lymnea spp., Potamopyrgus jenkinsi, Bithynia tentaculata
Chironomidae (Fresh)	Insect larvae from chironomids, also known as non-biting midges	
Arachnidae/Hydrachnidia	Water mite	Hydracarina spp.
Isopoda	Small, often flat crustaceans, with 7	Idotea spp., Jaera spp.

	symmetrical pairs of legs	
Cyanophtalma/Prostoma	Nemertean ("ribbon") worm, single freshwater species with two scientific names not fitting in other species groups	Cyanophtalma obscura/Prostoma graecense
Nematomorpha	Long, slender aquatic worms,also known as horsehair or Gordia worms	
Halicryptus spinulosus	Priapulid worm, both a detritivor and a predator. Lives burrowed in sediments, considered a "living fossil". Single species not fitting in other species groups	Halicryptus spinulosus
Ostracoda	Small crustaceans, also known as seed shrimp	

Table 1: Species groups in study, a brief description and example species found in the Baltic Sea

1.5 Theoretical framework

Previous studies in the Åland archipelago have found that benthic communities remain stable throughout seasons (Mattila, 1991), and that variations due to seasons alone are minimal at any given station (Bonsdorff & Blomqvist, 1989). While the species compositions of fish tend to vary based on the temperature of the environment, the assemblages of zoobenthos seem to be more affected by other abiotic and biotic factors, such as oxygen concentration, food availability and salinity (Bonsdorff & Blomqvist, 1993, Bonsdorff, et al., 1997).

2 Materials and Methods

2.1 Study area

Field work was carried out at 32 sites covering an area of approximately 140km2 in the archipelago of the western Gulf of Finland. The locations were made up of soft bottom habitats differing in size, exposure and vegetation. The area of the study ranged from the Hanko peninsula with open sea in the West to the Southeast side of the city of Tammisaari, a more sheltered area, in the East(see Figure 1), with salinity decreasing from 5.2‰ to 2.5‰ along a west-east axis.

Figure 1: Map of study area in relation to the south coast of Finland, made with Google Earth

Seasons in the Baltic Sea are very distinct, varying from surface temperatures of more than 20°C in the summer to an extensive ice cover in the winter time. As the Baltic Sea is practically closed off from the North Sea, it does not experience tides.

Other environmental parameters such as salinity, temperature, weather conditions, turbidity, nutrients, beach size, vegetation and rockiness of the sites were also recorded.

The sites were grouped into four location groups primarily based on their geographical locations, but also by differing habitats based on environmental parameters, namely beach length, salinity and exposure (see Table 2 for location descriptions and grouping criteria, and Figures 2, 3, 4 and 5 for maps of each location).

Location group	**Site number and name**	**Site Coordinates (EUREF-FIN WGS84)**		**Criteria, main criterion in bold**
A – Outer Archipelago 1	1 Tulludden	59 49 421	22 55 767	**Long beaches (> 200m)**
	2 Kolaviken	59 49 568	22 59 331	Salinity >4.5 ‰
	3 Neljän tuulen tupa	59 49 520	23 01 112	Exposed (Exposure >3.92)
	5 Vedagrundet	59 49 569	23 07 264	
	15 Syndalens bastu	59 52 157	23 13 712	

	16 Lappvik strand	59 53 665	23 13 793	
B – Outer Archipelago 2	4 Kattrumpan	59 49 446	23 02 883	**Small beaches (< 78m)** Salinity 4.9-5.2 ‰ Exposed (exposure 2.47-4.86)
	6 Högholmen	59 49 669	23 08 613	
	7 Klobban	59 49 859	23 10 722	
	8 Landbjörskä	59 49 826	23 10 877	
	9 Vindskär	59 49 690	23 12 606	
	10 Mellanskär	59 49 196	23 17 824	
	11 Rovholmen	59 50 281	23 15 108	
	12 Krogarvik (TV)	59 50 672	23 14 987	
	13 Brännskärs lagun	59 50 657	23 16 336	
	14 Långholmsbranten	59 51 038	23 14 573	
C – Middle Archipelago	17 Fabrik	59 54 012	23 15 951	**Salinity 4.0-5.2 ‰** **Sheltered (exposure 3.08-3.72)**
	18 Predium	59 54 482	23 17 465	
	19 Hermansö	59 53 023	23 19 847	
	20 Mörnäsudden	59 53 456	23 21 883	
	21 Verkholms fladan	59 52 187	23 24 866	
	22 Saltvik S (N)	59 53 676	23 25 521	
	23 Saltvik	59 53 846	23 25 514	
	24Ängholmen (Tjurholmen)	59 53 654	23 26 093	
D – Inner archipelago	25 Skogby (Herrgård)	59 55 573	23 19 864	**Salinity < 4 ‰** Sheltered (exposure 3.46-3.93)
	26 Vitsandsberget (Bastustugan)	59 26 112	23 21 817	
	27 Källan	59 56 570	23 22 691	
	28 Leksvall	59 56 901	23 22 807	
	29 Ekenäs simstrand	59 58 559	23 25 780	
	30 Ramsholmen	59 57 996	23 25 388	
	31 Ormnäs	59 57 892	23 26 878	
	32 Flyet (Vid bron)	59 58 248	23 28 271	

Table 2: Grouping of study sites, their locations and criteria for grouping

Figure 2: Map of sites in Outer Archipelago 1, made with Google Earth

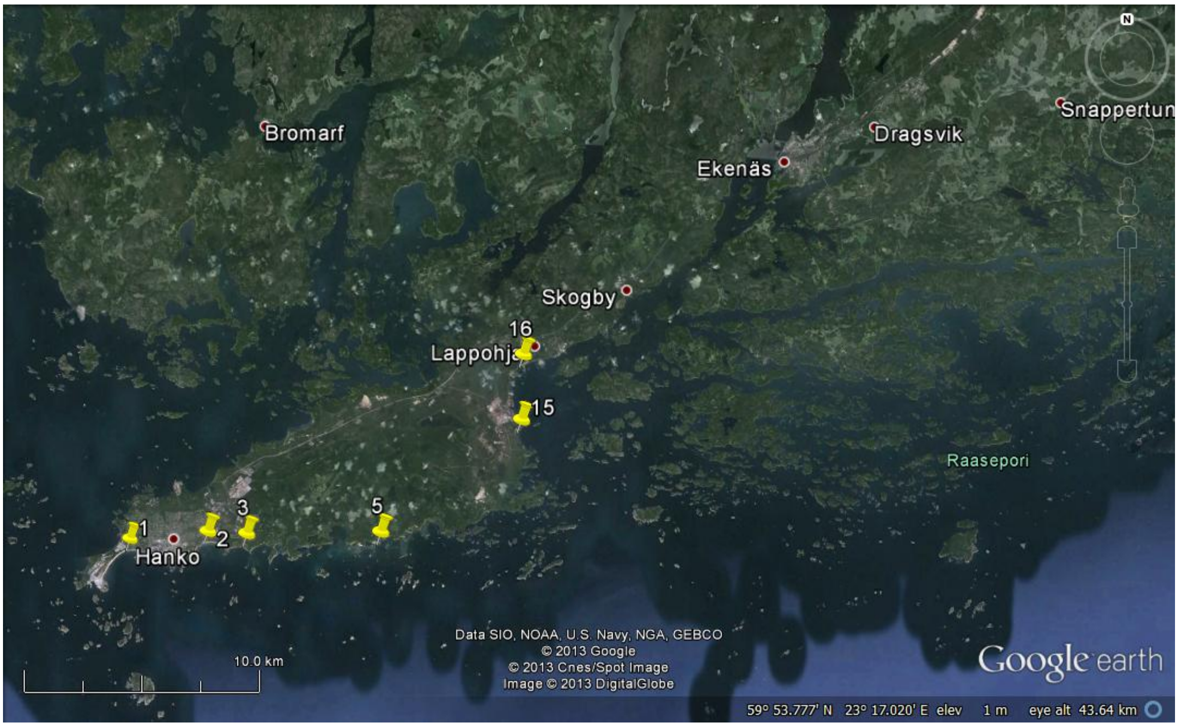


Figure 3: Map of sites in Outer Archipelago 2, made with Google Earth

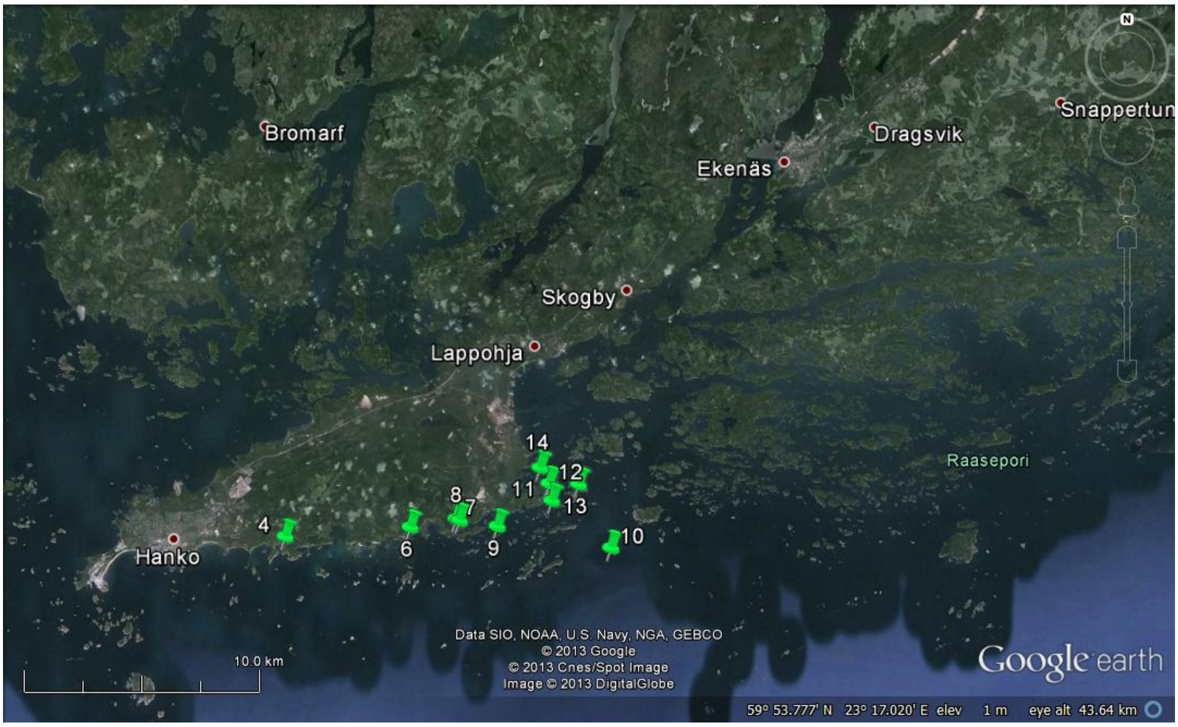
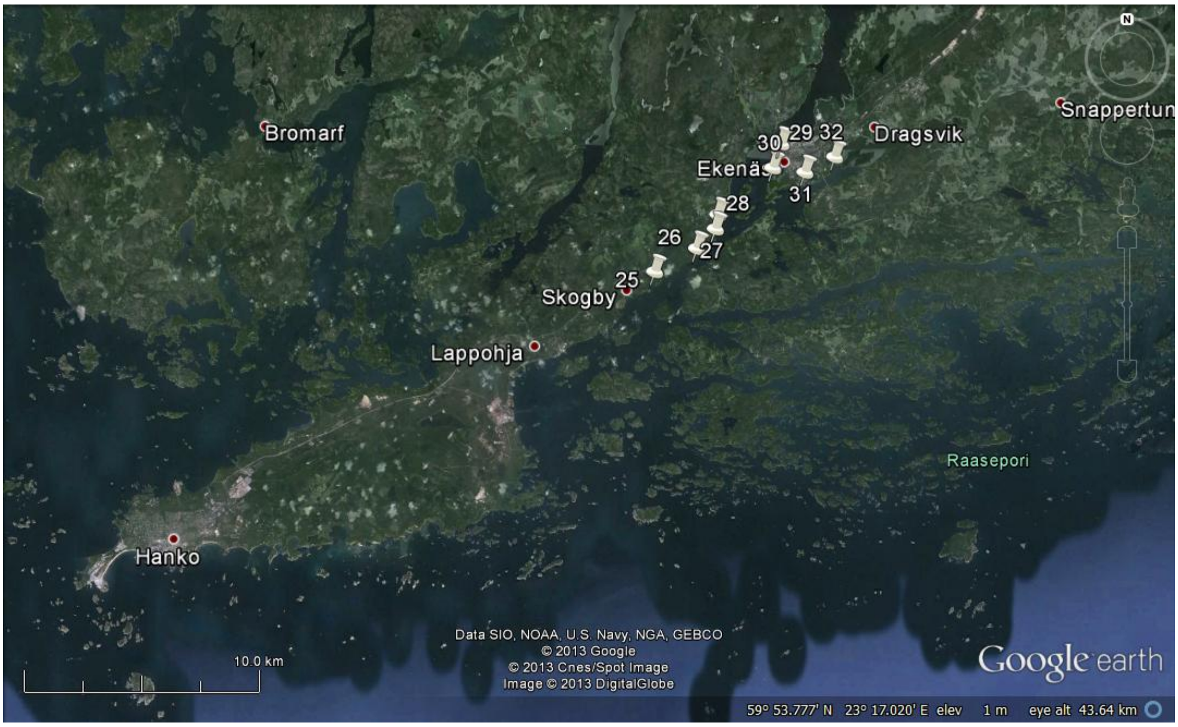


Figure 4: Map of sites in Middle Archipelago, made with Google Earth

Figure 5: Map of sites in Inner Archipelago



2.2 Collecting benthic samples

A total of 144 benthic samples were collected on two separate occasions in 2009; the spring samples were collected in April, while the summer samples were collected between

June and July. The samples were collected from 0.5 metres depth by wading at the locations, with the aid of a 21cm long plastic tube core sampler with a diameter of 4.5cm. A total of 3 replicate samples per site were collected for the summer samples, with the amount of replicates for the spring samples varying between 1 and 5 per site. The samples were stored in either glass jars or plastic film containers according to their respective volumes, and treated with a 70% alcohol solution. The samples were also treated with a Rose Bengal dye to facilitate separating organic matter from sand.

2.3 Analysis of benthic samples

The benthic samples were analysed between November 2011 and January 2012, using the swash-technique (Holme 1964, Hunt *et al* 2007). The contents of each sample were poured into a small bucket, their containers were rinsed, and the bucket was filled with tap water to approximately one third of the volume of the bucket. The bucket was then stirred vigorously, suspending organic matter in the water column, while the heavier sand remained at the bottom of the bucket. The bucket was then drained through a 0.5mm sieve, and care was taken to make certain that most of the sand stayed in the bucket. These steps were repeated 3 times for each sample to ensure that most organic material was collected in the sieve. The sand was then poured onto a tray and carefully examined with the help of a lighted magnifying glass to make sure that no organic material remained mixed in the sand. This process was facilitated by the rose Bengal dye, which colours all organic matter in a vibrant shade of red. The contents of the sieve were transferred to a petri dish and analysed under a microscope. The fauna in the sample were identified to the lowest possible taxa, and all individuals present in the sample were counted.

2.4 Statistical analysis

The data was analyzed using SPSS and PRIMER software (Clarke & Warwick, 2001).

The mean abundance of individuals within species groups and their standard deviations were calculated.

Shannon-Wiener Biodiversity Indices and species richness were calculated for both seasons within each location group and compared between seasons with independent samples Mann-Whitney U-tests separately for each location group. Species richness is a simple measure which describes the number of species in a given sample, while the Shannon-Wiener Biodiversity index, calculated by the formula $H' = -\sum_{i=1}^{R} p_i \ln p_i$, where p_i is the proportion of species belonging to species group i, allows the abundances of each species present to be considered. The Mann-Whitney U-test was selected as it allows the comparison of nonparametric data.

A square root transformation was applied before conducting SIMPER (Similarity percentage) and ANOSIM (Analysis of similarities) analyses. A dummy variable was added to minimize the problems caused by many zeros (absences) in the data. The ANOSIM, the analysis of similarities, measurement is based on the Bray-Curtis dissimilarity index, which shows the extent to which the assemblages differ from one another, with 0 indicating a complete similarity between samples and 1 indicating a complete dissimilarity between samples. SIMPER takes this measurement further, and identifies the groups which contribute most to the observed differences between groups.

The SIMPER analysis was repeated with a presence/absence transformation to eliminate the effect of more abundant species, allowing the detection of changes in rarer, less abundant species groups.

The species groups mainly responsible for the dissimilarities between seasons were identified in both square root and presence/absence transformed data, and the significances of changes in the distributions of the three most discriminating taxa across seasons were analyzed with independent samples Mann-Whitney U-tests.

3 Results

3.1 Descriptive statistics

The average abundance of marine bivalves decreased in all locations between spring and summer. The average abundance of marine gastropods decreased in Outer Archipelago 1, Middle archipelago and Inner archipelago, and increased slightly in Outer archipelago 2 between spring and summer (see Table 3 and Table 4). The average abundance of freshwater gastropods increased in Outer Archipelago 1, while decreased in other location groups.

Ostracods were not found in Outer Archipelago 1 in either spring or summer, and their average abundance increased from spring to summer in all other locations.

The average abundance of amphipods decreased in Outer Archipelago 1 and 2, while in the Middle and Inner Archipelago they went from absent to present. Isopods were only found in the Outer Archipelago 2 in the spring and Outer Archipelago 1 in the summer. Mysids were only found in one sample in the Inner Archipelago in the summer.

For a graphic representation of further descriptive information, such as number of species per site, see Appendix A.

	Outer Archipelago 1 (Location A)				Outer Archipelago 2 (Location B)			
Species group	Spring		Summer		Spring		Summer	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Bivalvia	.50	1.000	.44	1.423	2.08	2.275	1.40	2.343
Marine Gastropoda	0.00	0.000	.06	.236	3.17	5.967	5.03	14.318
Freshwater Gastropoda	.08	.289	.28	.752	2.75	3.957	2.10	3.556
Ostracoda	0.00	0.000	0.00	0.000	1.25	2.527	5.80	11.740
Amphipoda	2.58	3.029	1.28	2.608	.75	1.765	.07	.254
Mysida	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Isopoda	0.00	0.000	.22	.732	.08	.289	0.00	0.000
Chironomidae	0.00	0.000	1.22	3.173	0.00	0.000	2.07	4.017
Nematoda	.75	1.545	5.22	7.720	2.00	3.303	15.77	20.326
Nematomorpha	.08	.289	.11	.471	0.00	0.000	.13	.346
Cyanophtalma/ Prostoma	.08	.289	.61	1.037	.25	.452	.67	1.093
Polychaeta	0.00	0.000	.28	.575	.50	.905	2.03	4.072
Oligochaeta	.83	1.528	1.33	2.567	15.42	21.082	11.37	15.990
Arachnidae	0.00	0.000	0.00	0.000	0.00	0.000	.07	.254
Halicryptos spinulosus	.08	.289	.06	.236	0.00	0.000	.03	.183

Table 3: Mean abundances and standard deviations of individuals per species group in Outer Archipelago 1 and Outer archipelago 2

	Middle Archipelago (Location C)				Inner Archipelago (Location D)			
Species group	Spring		Summer		Spring		Summer	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Bivalvia	5.75	4.892	2.42	1.886	.06	.250	.04	.204
Marine Gastropoda	16.63	16.767	1.21	1.560	.25	.775	.08	.408

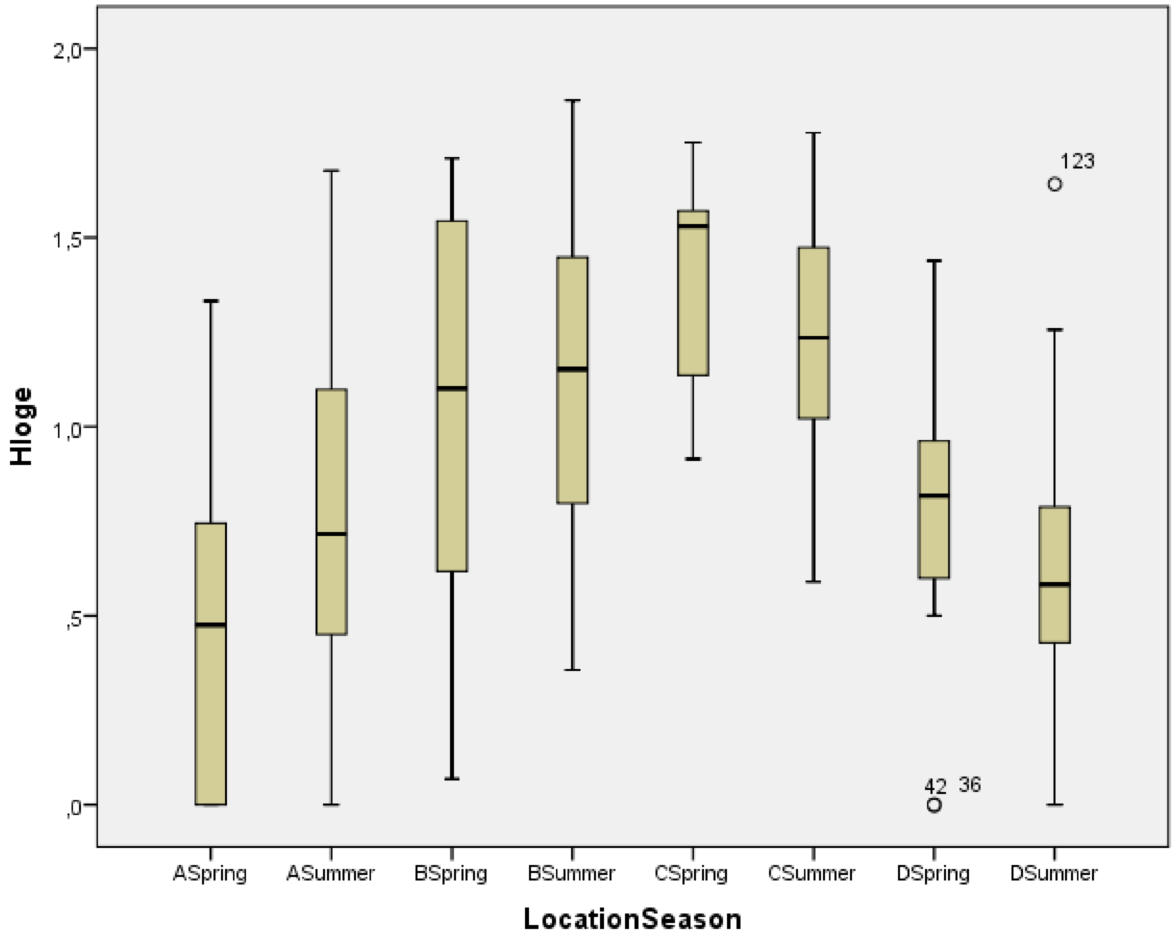
Freshwater Gastropoda	4.75	6.453	1.46	2.734	1.06	2.462	.13	.448
Ostracoda	.63	1.188	.83	2.036	0.00	0.000	.25	.608
Amphipoda	0.00	0.000	.04	.204	0.00	0.000	.04	.204
Mysida	0.00	0.000	0.00	0.000	0.00	0.000	.29	1.429
Isopoda	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Chironomidae	1.25	2.765	.83	2.180	1.25	1.844	1.54	3.243
Nematoda	5.00	8.246	21.04	21.265	2.13	5.018	45.25	159.855
Nematomorpha	.13	.354	.08	.282	0.00	0.000	.17	.482
Cyanophtalma/ Prostoma	.13	.354	.96	1.334	.31	.793	.25	.897
Polychaeta	3.25	2.188	2.83	3.422	.44	.512	.92	1.767
Oligochaeta	8.63	7.009	14.83	17.924	.81	1.047	2.71	6.497
Arachnidae	0.00	0.000	0.00	0.000	0.00	0.000	.04	.204
Halicryptos spinulosus	0.00	0.000	.13	.338	0.00	0.000	0.00	0.000

Table 4: Mean abundances and standard deviations of individuals per species group in Middle Archipelago and Inner Archipelago

3.2 Biodiversity

Biodiversity, as indicated by the values of Shannon-Wiener biodiversity indices (H'), did not vary significantly between seasons at any location (Independent samples Mann-Whitney U-test, p=0.104 for location group A, p=0.731 for location group B, p=0.220 for location group C, p=0.188 for location group D)(see Figure 6).

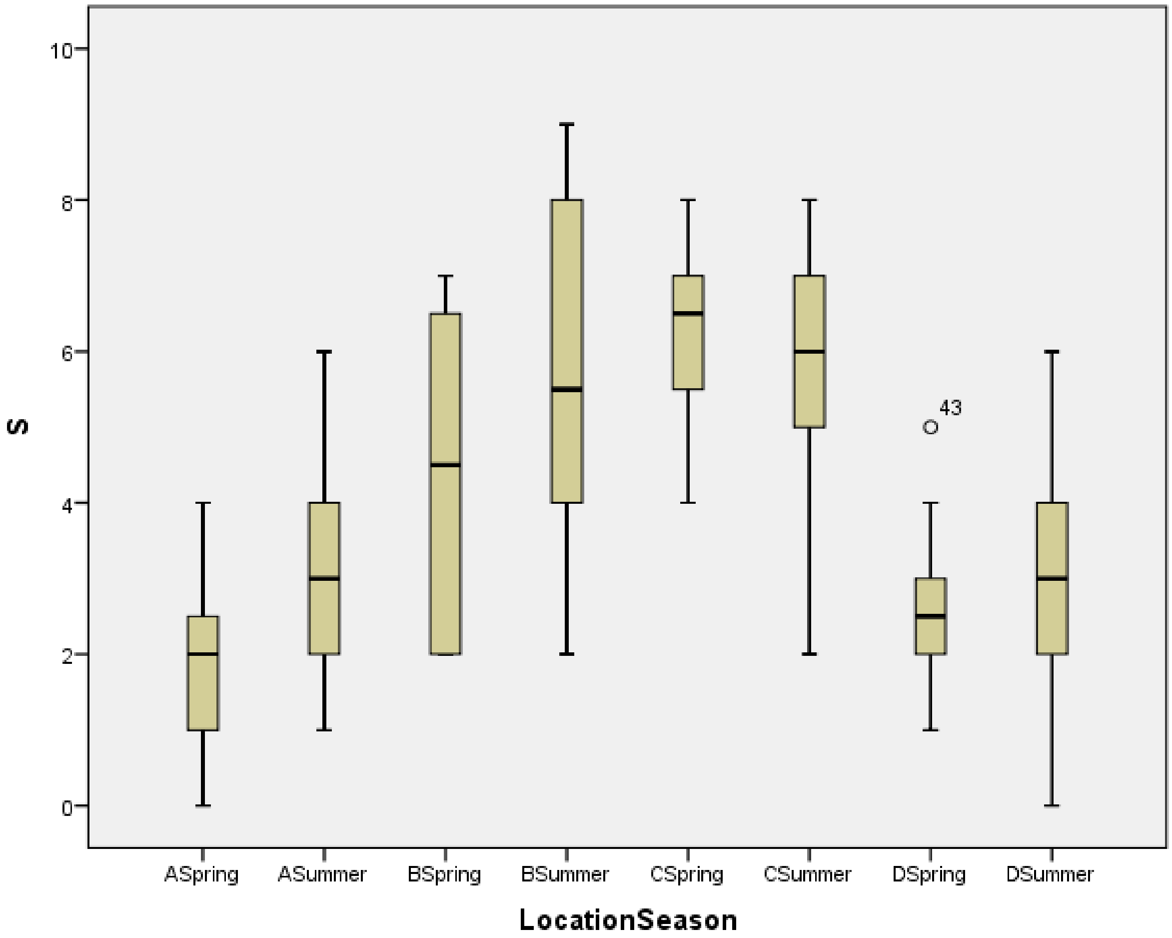
Figure 6: Values of Shannon-Wiener Biodiversity Indices (H', here expressed as the natural logarithm of H') for each location and season



3.3 Species richness

Species richness (S, see Figure 7) was found to increase significantly from spring to summer in location group A (Independent samples Mann-Whitney U-test, p=0.031). The difference was not significant in location group B (Independent samples Mann-Whitney U-test, p=0.130), location group C (p=0.480) or location group D (p=0.576).

Figure 7: Values of species richness (S) for each location and season



3.4 Analysis of Similarities

Analysis by ANOSIM indicated a slight variation between seasons in Outer archipelago 1 (Group A) and Outer archipelago 2 (Group B)(R=0.106 at 4.5% significance for Group A, R=0.148 at 4.6% significance for Group B, where the value 1 for R indicates complete dissimilarity and 0 complete similarity between seasons). The detected variation cannot be considered significant in the case of Middle archipelago (Group C) and Inner archipelago (Group D) (R=0.158 at 7.2% significance and R=0.131 at 9% significance, respectively).

3.5 Identifying Differences in Species Groups

The slight dissimilarities between seasons in location groups can be examined further through SIMPER analysis based on Bray-Curtis dissimilarity index, which indicates the species groups that mostly contribute to the observed differences.

3.5.1 Outer Archipelago 1

The SIMPER analysis (square root transformed) indicates that the species groups mainly contributing to the observed (although overall minimal) differences in seasons for location group A are Nematoda (25.88%), Amphipoda (22.74%) and Oligochaeta (14.39%). The presence/absence transformed SIMPER analysis identified the same species groups. Mann-Whitney U-tests conducted on the abundances of these species indicate that this difference is significant in the case of Nematoda (p= 0.031), and insignificant in the case of Amphipoda (p=0.158) and Oligochaeta (p=0.465).

3.5.2 Outer Archipelago 2

The square root transformed SIMPER data indicated the species groups mainly responsible for the observed differences between seasons are Oligochaeta (19.88%), Nematoda (18.14%) and Marine Gastropoda (10.80%). Mann-Whitney U-tests conducted on the abundances of these species reveal that the difference is significant in the case of Nematoda (p=0.001), and insignificant in the cases of Oligochaeta (p=0.198) and Marine Gastropoda (p=0.771).

Presence/absence transformed SIMPER identified Polychaeta (11.87%), Freshwater Gastropoda (10.80%) and Bivalvia (10.78%) as the differentiating species groups, but the changes in their distributions could not be considered significant (Independent samples Mann-Whitney U-test, p=0.060, p=0.670 and p=0.229, respectively).

3.5.3 Middle Archipelago

The square root transformed SIMPER data indicated the species groups mainly responsible for the observed differences between seasons are Marine Gastropoda (21.48%), Nematoda (20.32%) and Oligochaeta (12.85%).

Mann-Whitney U-tests conducted on the abundances of these species reveal that the difference is significant in the case of Marine Gastropoda (p=0.003), and insignificant in the cases of Nematoda (p=0.78) and Oligochaeta (p=0.623)

Presence/absence transformed SIMPER identified Cyanophtalma/Prostoma (16.38%), Freshwater Gastropoda (15.93%) and Marine Gastropoda (45.14%) as the differentiating species groups.

The changes in distribution are significant in the cases of Cyanophtalma/Prostoma and Marine Gastropoda (Independent samples Mann-Whitney U-test, p=0.046 and p=0.003, respectively). The changes could not be considered significant in the case of Freshwater Gastropoda, although the results are right at the limit of the 95% confidence interval (Independent samples Mann-Whitney U-test, p=0.051).

3.5.4 Inner Archipelago

The square root transformed SIMPER data indicated the species groups mainly responsible for the observed differences between seasons in the Inner Archipelago are Nematoda (35.68%), Oligochaeta (15.23%), Chironomidae(13.72%).

Out of these, the changes can be considered significant for Nematoda (Mann-Whitney U-test, p=0.001), while remaining insignificant for Oligochaeta (Mann-Whitney U-test, p=0.307) and Chironomidae (Mann-Whitney U-test, p=0.874)

The presence/absence transformed SIMPER analysis identified Polychaeta (15.82%) as a species group contributing to the dissimilarity between seasons in addition to Nematoda (17.06%) and Oligochaeta (16.41%). The differences in the distribution of polychaeta were not significant (independent samples Mann-Whitney U-test, p=0.777).

4 Discussion

Overall, the results indicate that there are no significant fluctuations in either species group biodiversity or species richness between the spring and summer seasons in most location groups.

These findings correspond to previous studies (Mattila, 1991, Bonsdorff & Blomqvist, 1989), which stated that benthic communities remain stable throughout seasons. Changes between seasons, therefore, could be indicative of changes in other biotic and abiotic factors (Bonsdorff & Blomqvist, 1993).

Species richness was found to increase in the summer in Outer Archipelago 1, where marine gastropods, isopods and Chironomidae were found in the summer but not in the spring. Bonsdorff, et al. (1997) found species richness to be positively correlated with oxygen saturation of the bottom waters. This might suggest an improvement in the oxygen conditions in Outer Achipelago 1 from spring to summer. Although the differences in species richness, which only takes into account the number of species present, appeared significant in Outer Archipelago 1, differences in the abundances of species were not significant. The results also do not indicate significant changes in the species group compositions between the seasons.

The most striking changes were found in the abundance of nematodes, which made up the most abundant species group in all location groups in the summer samples, despite making up the most prominent group of fauna only in the Inner archipelago in the spring. The differences in the abundances of nematodes were significant in Outer archipelago 1, Outer archipelago 2 and Inner archipelago. Ojaveer, et al (2010) have shown that they are the only group of fauna not eliminated by oxygen deficiency, allowing them to flourish more than other species groups in eutrophic conditions. This may indicate a potential reduction in oxygen conditions between the seasons.

In addition to the changes in the abundance of nematodes, the only other significant differences found in the study were observed in the Middle archipelago, where the abundances of Cyanophtalma/Prostoma were found to increase from spring to summer, while the abundances of marine gastropods decreased.

5 Critique for study

Overall, the results of this study are inconclusive, and permit very limited speculation. Further study is needed to examine the causes behind the increase in the abundance of nematodes and the significance of such findings.

As the scope of this Bachelor’s thesis study needed to be limited, the species were mainly identified or grouped at the level of Order or Family. A more specific taxonomic resolution could have yielded more specific and relevant results.

The samples for the study were collected in the spring and summer of 2009. For the scope of seasonality, a more purposeful selection of sampling times would make sense. For example, hypoxia has been shown to be at its greatest between August and September (Conley, et al., 2011). Selecting times that are known to reflect important environmental events such as algal blooms, annual hypoxic maximums and, for comparison, more optimal conditions could be beneficial in producing more pronounced and relevant results, especially in the context of an applied discipline such as Integrated Coastal Zone Management.

6 Acknowledgements

I would like to thank Janica Borg for her supervision and help in writing this thesis as well as providing the samples for the study, Purba Pal for arranging practical matters and providing initial supervision, Patrik Kaufvelin for his consultation in statistics, Anna Granberg for her continuous support, Tvärminne Zoological Station for assistance in providing supplies, Yrkeshögskolan Novia for providing a lab space for the analysis of samples, and finally Eliecer Diaz for acquainting me with the lab work involved in analyzing benthic samples.

7 Works Cited

Bonsdorff, E. & Blomqvist, 1993. Biotic Couplings on Shallow Water Soft Bottoms - Examples from the Northern Baltic Sea. Oceanogr. Mar. Biol. Annu. Rev., Volume 31, pp. 153-176.

Bonsdorff, E. & Blomqvist, E., 1989. Do exceptional winters affect the zoobenthos and fish in shallow, brackish archipelago waters? An example from the northern Baltic Sea. Memoranda Societatis pro Fauna et Flora Fennica, Volume 65, pp. 47-53.

Bonsdorff, E., Blomqvist, E., Mattila, J. & Norkko, A., 1997. Coastal Eutrophication: Causes, Consequences and Perspectives in the Archipelago Areas of the Northern Baltic Sea. Estuarine, Coastal and Shelf Science, 44(Supplement A), pp. 63-72.

Clarke, K. & Warwick, R., 2001. *Change in marine communities: an apporach to statistical analysis and interpretation.* 2 red. Plymouth: PRIMER-E.

Conley, D. J. o.a., 2011. Hypoxia Is Increasing in the Coastal Zone of the Baltic Sea. *Environmental Science & Technology,* 45(16), pp. 6777-6783.

HELCOM, 2009. *Biodiversity in the Baltic Sea - An integrated thematic assessment on biodiversity and nature conservation in the Baltic Sea.* u.o., Helsinki Comission.

Holme, N.A. 1964. Methods of sampling the benthos. — *Advances in Marine Biology*

2:171-260.

Hunt, H. L, Maltais, M.-J., Fugate, D.C. and Chant, R. J. 2007. Spatial and temporal variability in juvenile bivalve dispersal: effects of sediment transport and flow regime. — *Marine Ecology Progress Series* 352: 145-159.

Jonsson, P. C. R. W. F., 1990. Laminated sediments in the Baltic - a tool for evaluating nutrient mass balance. Volym 19, pp. 152-158.

Mattila, J., 1991. Seasonal and spatial variation in the diet of perch (Perca fluviatilis L.) in a shallow soft-bottom area (SW Finland). Proceedings of the 12th Baltic Marine Biologists Symposiuml, 25-30 August, pp. 101-107.

Ojaveer, H. o.a., 2010. *Status of Biodiversity in the Baltic Sea.* [Online]
Available at: doi:10.1371/journal.pone.0012467
[Använd 10 February 2013].

Rumohr, H., Bonsdorff, E. & Pearson, T. H., 1996. Zoobenthic Succession in Baltic Sedimentary Habitats. *Archive of Fishery and Marine Research,* 44(3), pp. 179-213.

Save Our Baltic Sea, 2009. *About the Baltic Sea.* [Online]
Available at: http://www.saveourbalticsea.com/index.php/our-baltic-sea/about-the-baltic-sea/
[Använd 15 September 2013].

Wilson, M. J. & Kakouli-Duarte, T., 2009. *Nematodes as Environmental Indicators.* UK: MPG Books Group.

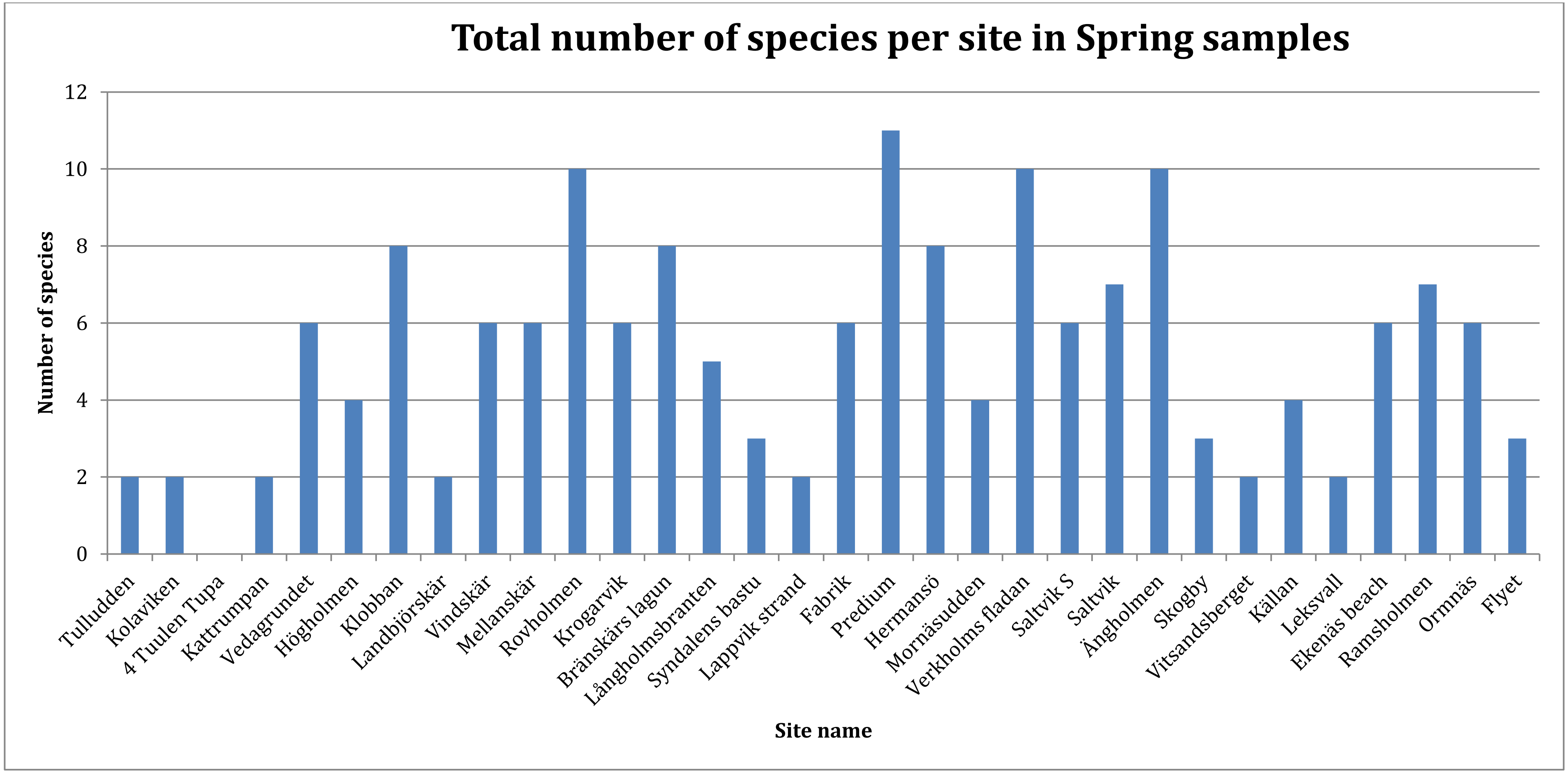
WWF Baltic Ecoregion Programme, 2009. *The Invisible Threat to the Baltic Sea: Spring Algae Blooms.* [Online]
Available at: http://awsassets.panda.org/downloads/4746_springalgaebloom_final.pdf
[Använd 4 December 2013].

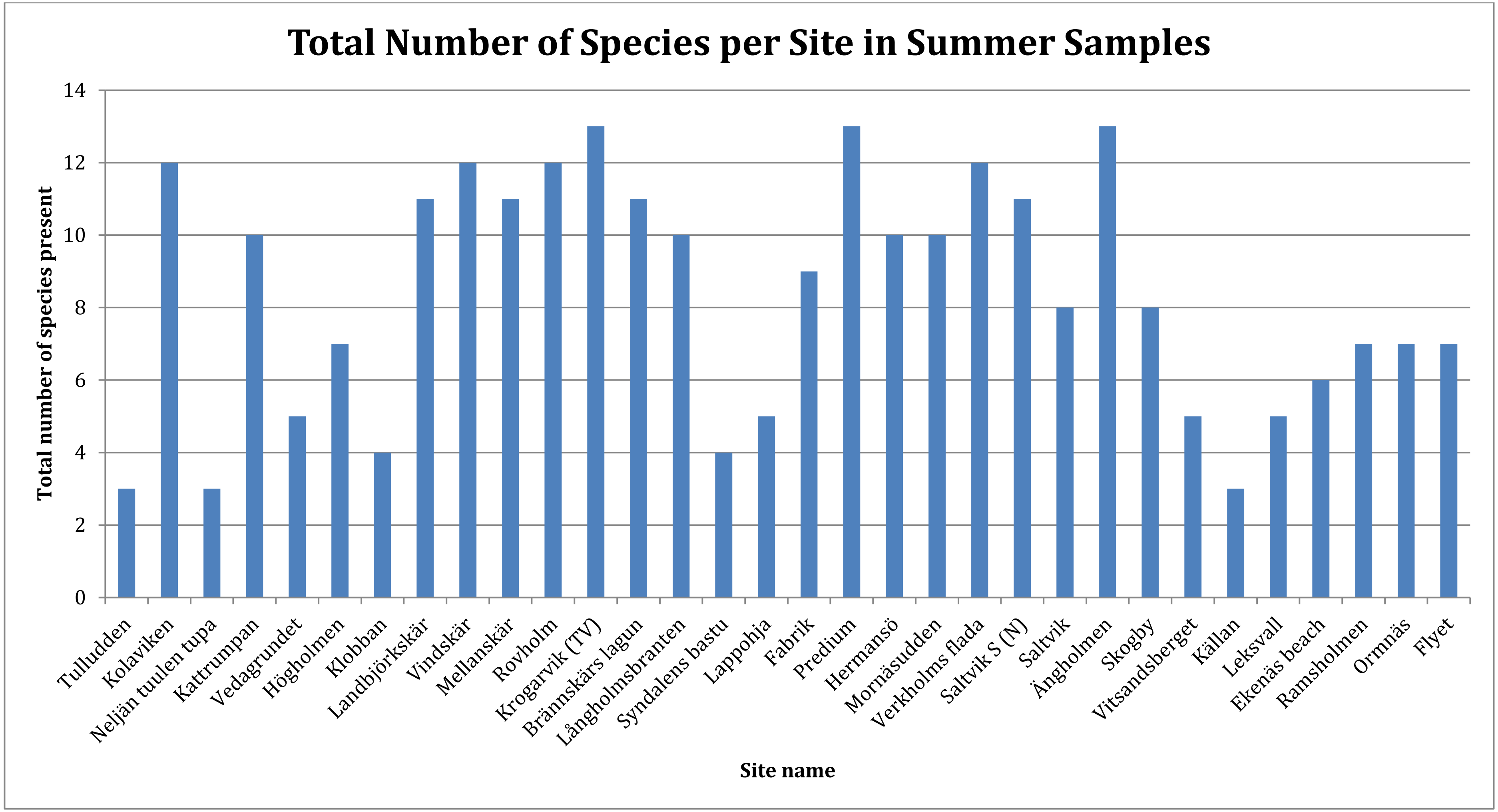
WWF, n.d. *Baltic Sea.* [Online]
Available at: http://wwf.panda.org/what_we_do/where_we_work/baltic/
[Accessed 1 October 2013].

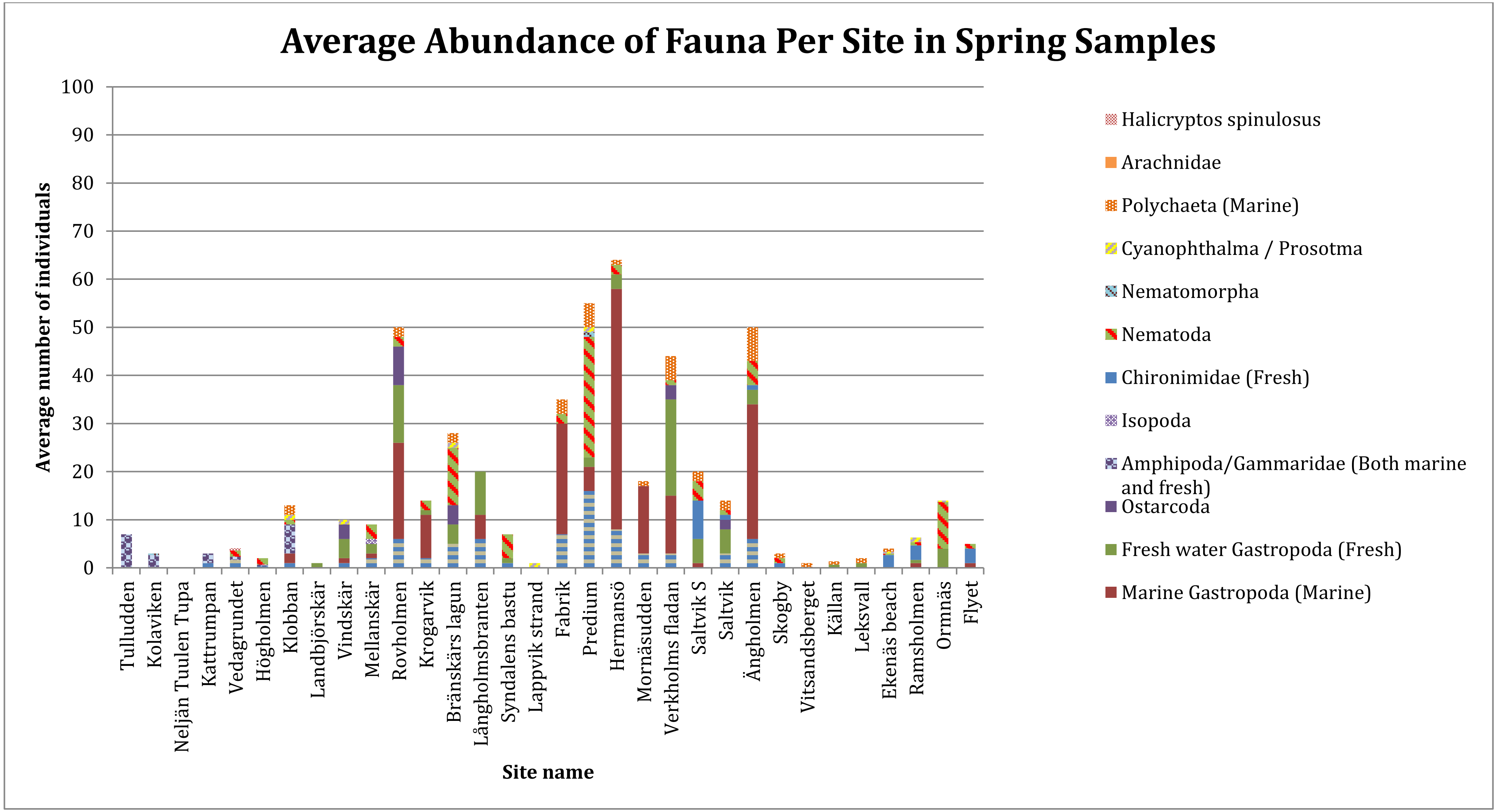
Zillén, L. o.a., 2008. Past occurrences of hypoxia in the Baltic Sea and the role of climate variability, environmental change and human impact. *Earth-Science Reviews,* 91(1-4), pp. 77-92.

Appendices

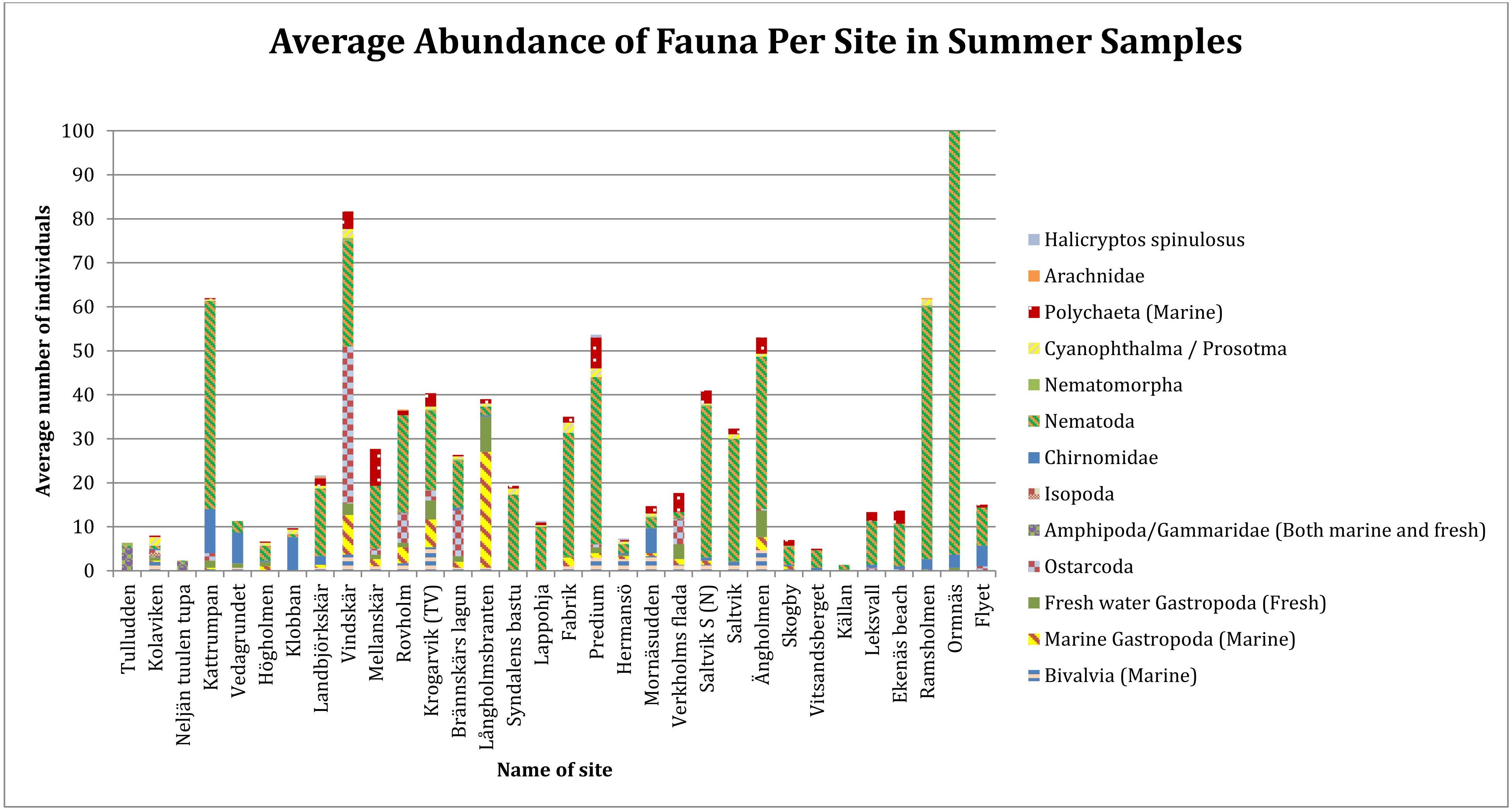
Appendix A: Graphic representations for total number of species per site and average and relative abundance of fauna per site



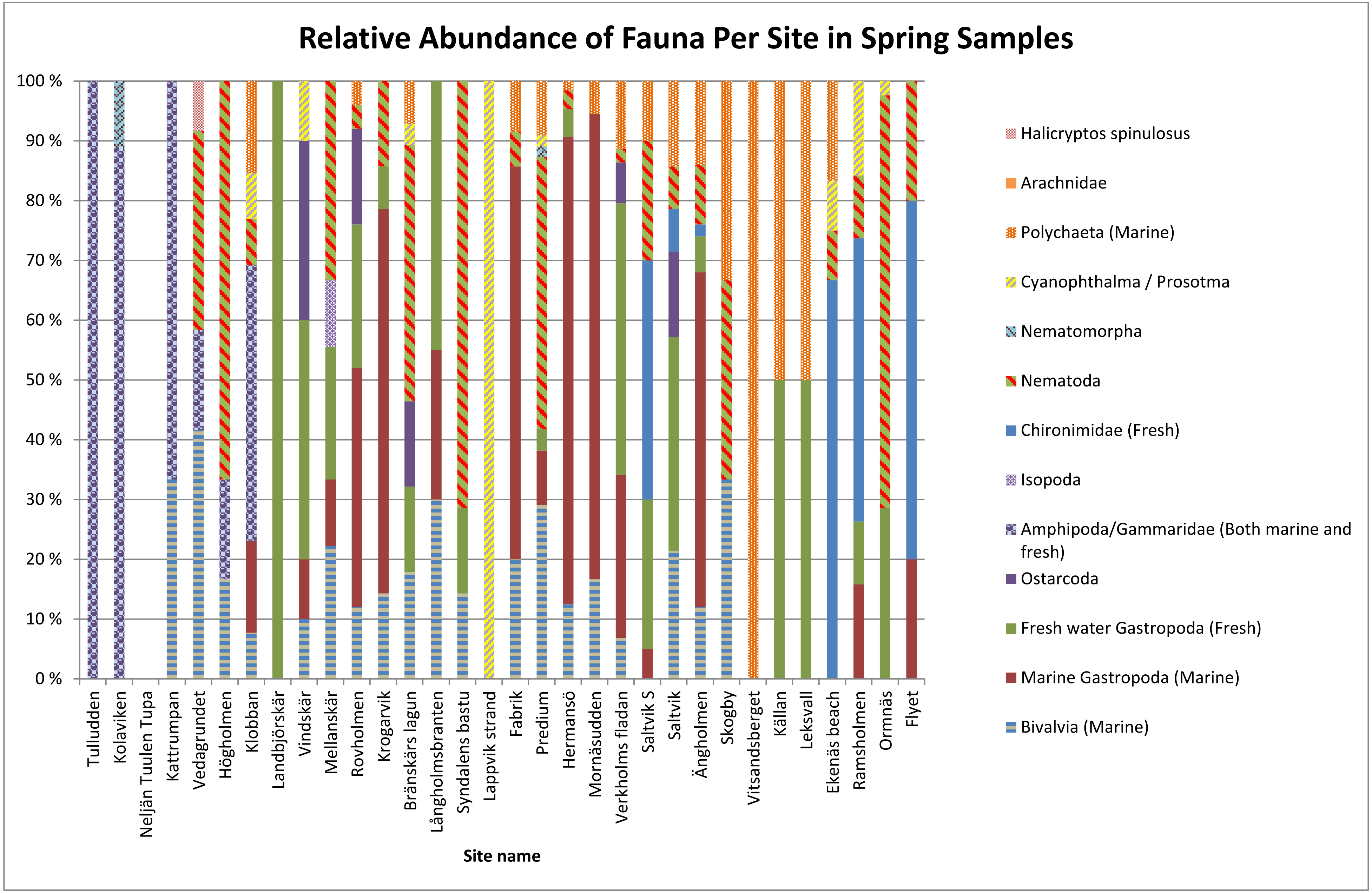

Total Number of Species per Site in Summer Samples
Total number of species present
0
2
4
6
8
10
12
14
Tulludden
Kolaviken
Neljän tuulen tupa
Kattrumpan
Vedagrundet
Högholmen
Klobban
Landbjörkskär
Vindskär
Mellanskär
Rovholm
Krogarvik (TV)
Brännskärs lagun
Långholmsbranten
Syndalens bastu
Lappohja
Fabrik
Predium
Hermansö
Mornäsudden
Verkholms flada
Saltvik S (N)
Saltvik
Ängholmen
Skogby
Vitsandsberget
Källan
Leksvall
Ekenäs beach
Ramsholmen
Ormnäs
Flyet
Site name

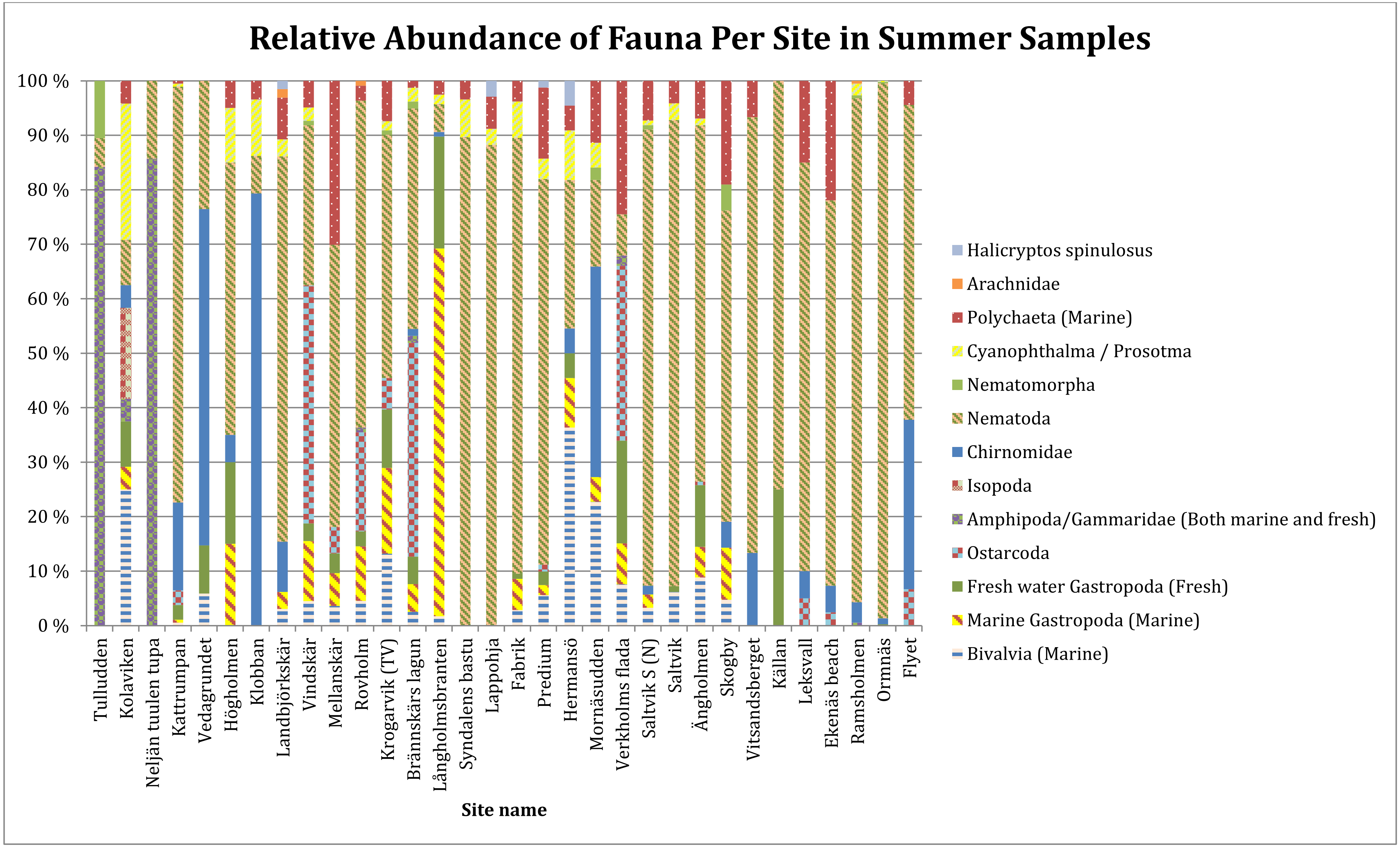


Average Abundance of Fauna Per Site in Spring Samples
100
90
80
70
60
50
40
30
20
10
0
Average number of individuals
Tulludden
Kolaviken
Neljän Tuulen Tupa
Kattrumpan
Vedagrundet
Högholmen
Klobban
Landbjörskär
Vindskär
Mellanskär
Rovholmen
Krogarvik
Bränskärs lagun
Långholmsbranten
Syndalens bastu
Lappvik strand
Fabrik
Predium
Hermansö
Mornäsudden
Verkholms fladan
Saltvik S
Saltvik
Ängholmen
Skogby
Vitsandsberget
Källan
Leksvall
Ekenäs beach
Ramsholmen
Ormnäs
Flyet
Site name
Halicryptos spinulosus
Arachnidae
Polychaeta (Marine)
Cyanophthalma / Prosotma
Nematomorpha
Nematoda
Chironimidae (Fresh)
Isopoda
Amphipoda/Gammaridae (Both marine and fresh)
Ostarcoda
Fresh water Gastropoda (Fresh)
Marine Gastropoda (Marine)



Average Abundance of Fauna Per Site in Summer Samples
Average number of individuals
100
90
80
70
60
50
40
30
20
10
0
Tulludden
Kolaviken
Neljän tuulen tupa
Kattrumpan
Vedagrundet
Högholmen
Klobban
Landbjörkskär
Vindskär
Mellanskär
Rovholm
Krogarvik (TV)
Brännskärs lagun
Långholmsbranten
Syndalens bastu
Lappohja
Fabrik
Predium
Hermansö
Mornäsudden
Verkholms flada
Saltvik S (N)
Saltvik
Ängholmen
Skogby
Vitsandsberget
Källan
Leksvall
Ekenäs beach
Ramsholmen
Ormnäs
Flyet
Name of site
Halicryptos spinulosus
Arachnidae
Polychaeta (Marine)
Cyanophthalma / Prosotma
Nematomorpha
Nematoda
Chirnomidae
Isopoda
Amphipoda/Gammaridae (Both marine and fresh)
Ostarcoda
Fresh water Gastropoda (Fresh)
Marine Gastropoda (Marine)
Bivalvia (Marine)


Relative Abundance of Fauna Per Site in Spring Samples
100 %
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
10 %
0 %
Tulludden
Kolaviken
Neljän Tuulen Tupa
Kattrumpan
Vedagrundet
Högholmen
Klobban
Landbjörskär
Vindskär
Mellanskär
Rovholmen
Krogarvik
Bränskärs lagun
Långholmsbranten
Syndalens bastu
Lappvik strand
Fabrik
Predium
Hermansö
Mornäsudden
Verkholms fladan
Saltvik S
Saltvik
Ängholmen
Skogby
Vitsandsberget
Källan
Leksvall
Ekenäs beach
Ramsholmen
Ormnäs
Flyet
Site name
Halicryptos spinulosus
Arachnidae
Polychaeta (Marine)
Cyanophthalma / Prosotma
Nematomorpha
Nematoda
Chironimidae (Fresh)
Isopoda
Amphipoda/Gammaridae (Both marine and fresh)
Ostarcoda
Fresh water Gastropoda (Fresh)
Marine Gastropoda (Marine)
Bivalvia (Marine)



Relative Abundance of Fauna Per Site in Summer Samples
100 %
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
10 %
0 %
Tulludden
Kolaviken
Neljän tuulen tupa
Kattrumpan
Vedagrundet
Högholmen
Klobban
Landbjörkskär
Vindskär
Mellanskär
Rovholm
Krogarvik (TV)
Brännskärs lagun
Långholmsbranten
Syndalens bastu
Lappohja
Fabrik
Predium
Hermansö
Mornäsudden
Verkholms flada
Saltvik S (N)
Saltvik
Ängholmen
Skogby
Vitsandsberget
Källan
Leksvall
Ekenäs beach
Ramsholmen
Ormnäs
Flyet
Site name
Halicryptos spinulosus
Arachnidae
Polychaeta (Marine)
Cyanophthalma / Prosotma
Nematomorpha
Nematoda
Chirnomidae
Isopoda
Amphipoda/Gammaridae (Both marine and fresh)
Ostarcoda
Fresh water Gastropoda (Fresh)
Marine Gastropoda (Marine)
Bivalvia (Marine)